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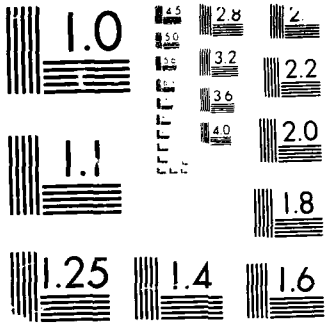

MICROCOPY RESOLUTION TEST CHART

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AUTOMATIC LINE NETWORK EXTRACTION FROM AERIAL IMAGERY OF URBAN AREAS THROUGH KNOWLEDGE BASED IMAGE ANALYSIS

Second Interim Report

20 May 1987

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1. Present Status

During the past 4 months work has been concentrated on three topics, namely application of road extraction methods to multiresolution test images, application of general segmentation methods to multiresolution test images, and design of a common data base for all intermediate results. These activities are explained to some detail in the following.

Multiresolution Test Images. The image analysis system, which we plan to develop and implement, requires access to different resolution levels of a test image. This feature provides for an easy adaptation of the processing methods to the variable size of segments contained in every image. We generate multiresolution images by subsequent averaging of the grey values of four adjacent pixels; this results in a series of image matrices (image pyramid) with a resolution (or size) decreasing by a factor of 2 from image to image. Examples are shown below.

Road Extraction. Methods for the detection of starting points and for the subsequent extraction of roads, which we had developed for other purposes, were applied to all test image pyramids. In general, the results complied to what we had expected: Fig. 1 shows a section of test image PH01 (Phoenix suburban housing area) with road extraction results overlayed in white colour (thin white lines hardly to be seen): some extraction results have been found within the housing area, in fact not the roads themselves, but the bright side walks; extraction results appear in two fields (upper left and right of the figure) and along the water way as well as the big access road (bottom of the figure). Fig. 3 shows a section of test

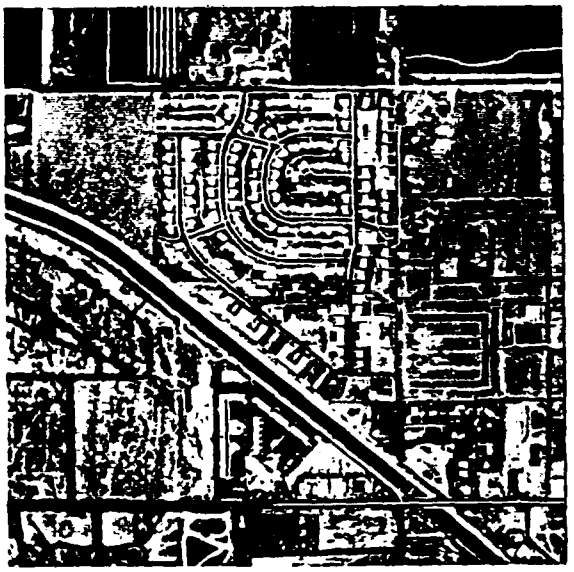

Fig. 1: Road extraction in test image PH01

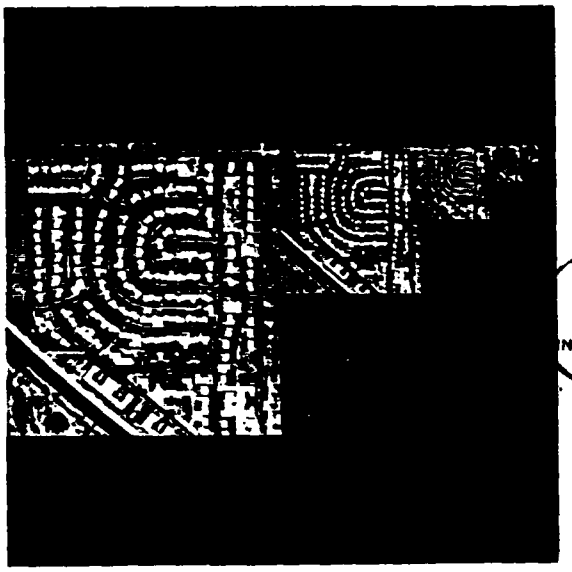

Fig. 2: Grey value pyramid of test image PH01

image BI00 (Bietigheim, Germany, suburban area) with extraction results overlayed in black colour: most of the road outside the housing area have been found, only a few road segments have been found within the housing area.

Confidence values will have to be computed for those extraction re-

Fig. 3: Road extraction in test image BI00

sults to prepare their use as input in the image analysis system. Homogeneity of road width and amount of contrast will be the two major contributions to this confidence measures.

General Image Segmentation. Fig. 2 shows a grey level pyramid (reduction factor of 2) of test image PH01. The base level image size is 512 x 512 pixels; hence, there exist 10 levels in this pyramid, which are named consecutively

- level 9, the base level image of (original) size 512 x 512 pixels,

- level 8, the first reduced size image of 256 x 256 pixels,

etc. through levels 7, 6, 5, 4, 3, and 2 down to

- level 1, the last reduced size "image" of 2 x 2 pixels,

- level 0, consisting of one single "pixel" of a grey value which equals the average grey value of all (original) pixels.

The upper levels 9 through 3 of the pyramid are discernable in Fig. 2. The road extraction methods have been applied to each image matrix of this series, using an unchanged set of default parameter values. The results are comparable to those shown in Fig. 1 and are not shown again. Fig. 4 and Fig. 5, however, show results of preparatory steps for the image segmentation process: in a systematic process, we compute local contrast measures in each matrix of the pyramid separately. Fig. 4 shows, for the upper levels 9 through 3 of the pyramid, results of a contrast measurement in a 2-dim subarea of 3 x 3 pixels: subareas with a positive contrast measure

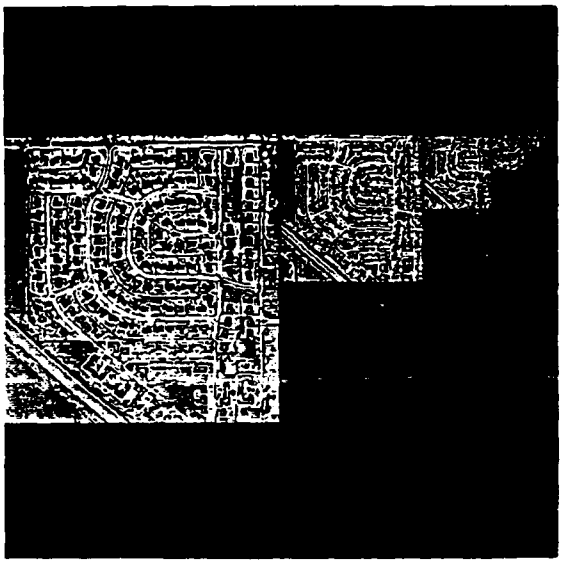

Fig. 4: The pyramid of all 2-dim local contrasts

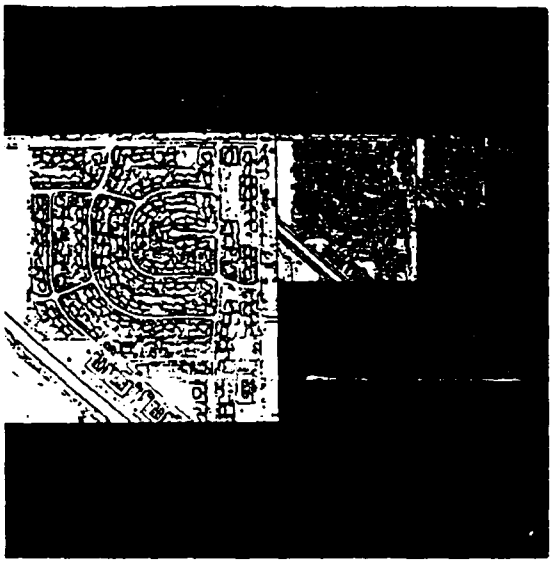

Fig. 5: The pyramid of essential 2-dim local contrasts

("bright spots") are shown in black, subareas without significant contrast ("homogeneous intensity") are encoded in medium grey tone, and subareas with a negative contrast measure ("dark spots") are encoded in white.

Spots contrasting significantly to their surroundings will be regarded as candidates for image segments. Due to the decreasing resolution in the different levels of the pyramid, candidate spots are cues for segments of increasing size, when referenced to the original. However, as we measure the contrast features in each level separately, we end up with a great amount of redundant spots pertaining to different details of the few major (meaningful) image segments. To reduce this redundancy we purge the set of spots to retain, for each coordinate, the relevant (essential) spot in the lowest possible level of the pyramid. Fig. 5 shows preliminary results of a purge operation applied to the pyramid of all contrast results (Fig. 4).

Segmentation of the image is the next processing step. With preknowledge about expected object size, we can access the contrast cues of specific resolution levels in the pyramid. The following figures show some results. Fig. 6 shows, for the purpose of visual orientation, the 512 x 512 input image in original resolution. Exploiting the contrast cues of levels 4 and 5 of the purged contrast pyramid produces segments of medium size as shown in Fig. 7. Using the contrast cues of the levels 4, 5, and 6 of the purged contrast pyramid yields segments of medium to small size as shown in Fig. 8. Before storing segmentation results for further processing, we extract the contours of the various segments which, for the segments of Fig. 8, are shown in Fig. 9.

The following series of seven figures shows results of the same processing steps for a section of test image BH00 (Bietigheim, Germany). There is the image pyramid (Fig. 10), the pyramid of all contrast cues (Fig. 11) and the pyramid of locally purged contrast cues (Fig. 12). Fig. 13 shows the input image in original resolu-

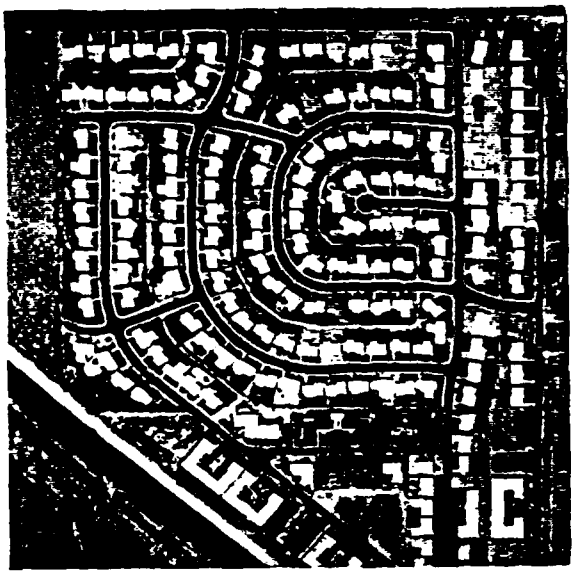

Fig. 6: Input image

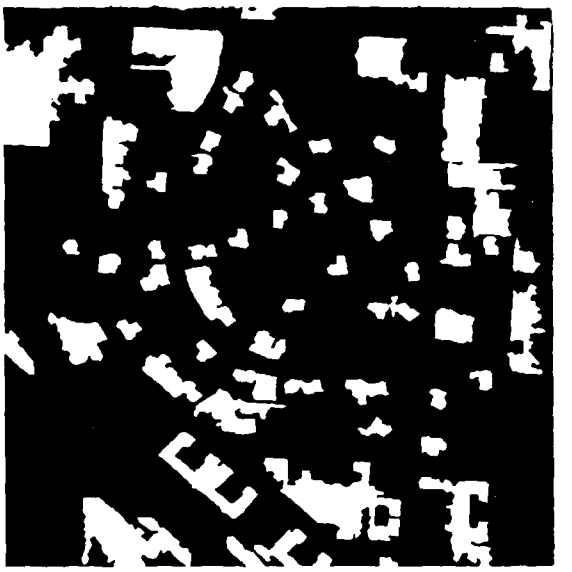

Fig. 7: Segments resulting of exploitation of contrast cues of levels 4 and 5

Fig. 8: Segments resulting from exploitation of contrast cues of levels 4, 5, and 6

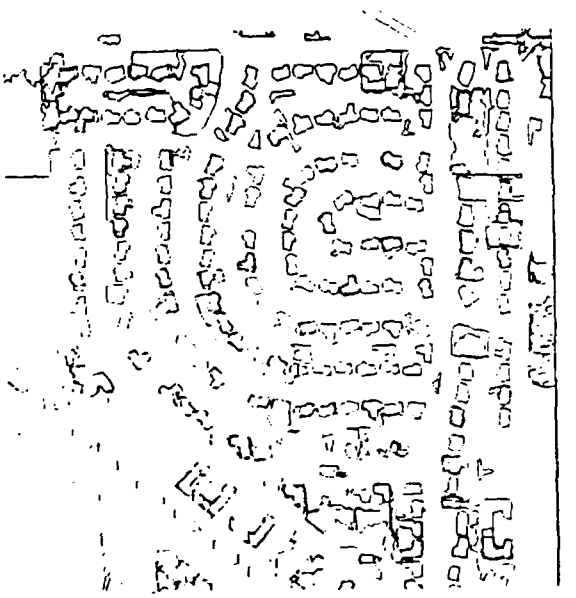

Fig. 9: Contour representation of the segments

tion; Figures 14 and 15 show the results of the segmentation process, when exploiting contrast cues of levels 4 and 5 or levels 4, 5, and 6 respectively. Fig. 16, at the end, again shows the contour representation of the segments in Fig. 15. Note, that a considerable part of the roads have already been segmented (Fig. 15), due to the properly adapted size and contrast thresholds.

These sets of segments will be merged with the road extraction results mentioned above to form the input to a grouping and subsequent interpretation process. Data structures for an organized storage of the results of all processing steps are based on semantic

Fig. 10: Grey value pyramid of test image BH00

Fig. 11: The pyramid of all 2-dim local contrasts

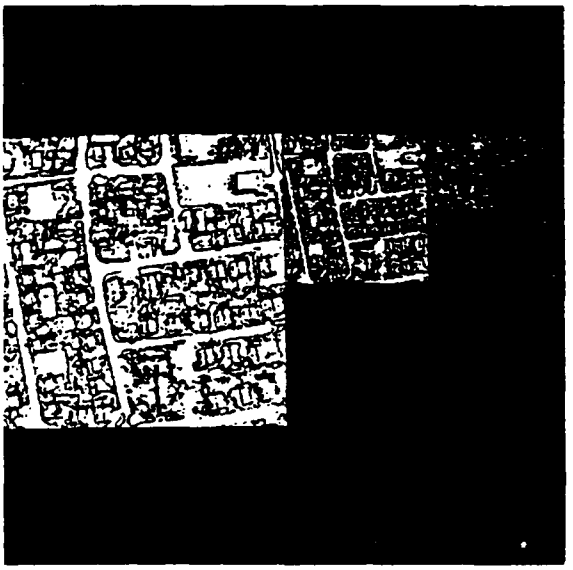

Fig. 12: The pyramid of essential 2-dim local contrasts

Fig. 13: Input image

net theory which is a well defined and powerful mechanism.

2. Continuation of Work

Work will be continued with more segmentation experiments, computation of confidence measures for the road extraction results, and implementation of an object oriented data base. Grouping and interpretation of (reliable) segmentation results will follow.

Fig. 14: Segments resulting from exploitation of contrast cues of levels 4 and 5

Fig. 15: Segments resulting from exploitation of contrast cues of levels 4, 5, 6

Fig. 16: Contour representation of the segments

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